

On the physical structure of radiant energy: waves and corpuscles

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Abstract

The physical principle at the beginning of electromagnetic waves is different from that of light. In fact electromagnetic waves are produced by modulation of current intensity of conduction electrons in metals that generates an electromagnetic field in the space. Light instead is made up of energy corpuscles, named photons, that are produced by electron quantum jumps among energy different levels of atom. In this paper a transition frequency from the wave nature of electromagnetism to the corpuscular nature of light is defined. We prove further that diffraction isn't an exclusive property of waves and an original interpretation of diffraction according to the corpuscular theory is furnished utilizing the Fourier integral. A theoretical explanation on propagation of photon is finally given through the new concept of electromagnetic nanofield.

1. Introduction

Light is the first shape of radiant energy that attracted people's attention and fascinated many men of science since antiquity. Only at the dawning of modern science (17th century) nevertheless the issue of the physical nature of light had a scientific explanation with the formulation of two theories: the wave theory and the corpuscular theory.

The wave theory supported by Huygens, Fresnel and Young claimed light propagates through space by mechanical oscillations of a transmissive medium called ether. Then in the 19th century Maxwell developed a wave electromagnetic theory^[1] in which electromagnetic waves propagate with the speed of light through oscillations of electromagnetic field. Like this Maxwell defined a complete equivalence between light and electromagnetic waves. The wave theory of light explains well some physical phenomena as diffraction and interference.

The corpuscular theory of light was first supported by Newton and then perfected by Planck and Einstein after the discovery of photon. In this theory light is a particle beam, just photons, that travel with the same velocity c . In the corpuscular theory medium isn't necessary to explain the ways of propagation of light like in Maxwell's theory. The corpuscular theory explains as well other different physical phenomena like the geometrical optics and the photoelectric effect.

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Still today scientific community parts between supporters of wave theory and supporters of corpuscular theory. Moreover, the issue on the physical nature of light has a strong importance for the theory of relativity because supporters of wave theory side largely with the theory of ether in all its different expositions (immobile ether, dragged ether, dragged partially ether, etcetera) while supporters of corpuscular theory side largely with the special relativity.

A synthesis between the two viewpoints has been attempted in the past and the wave-corpuscle dualism has been the result of this attempt.

Now here we will attempt to give an innovative solution to the issue departing from two theoretical hypotheses both proved by experimental results:

- a. The existence of photon
- b. The cogency of Maxwell's equations.

In particular the phenomenon of diffraction is explained normally by the wave theory, in this paper we show it can be explained as well in the corpuscular theory.

2. On the physical nature of electromagnetic waves

Radiant energy is generally classified according to frequency of radiation. Frequencies until 3KHz are used for transport of electric energy and for wire traditional telephony. The application of electromagnetic waves begins at the 3KHz frequency (ultralong waves) and reaches the 300GHz frequency (microwaves) where the infrared begins. Electromagnetic waves are generated by variation of current intensity of conduction electrons in metals. The variation of current intensity can be produced by a voltage signal that contains the information to transmit (fig.1).

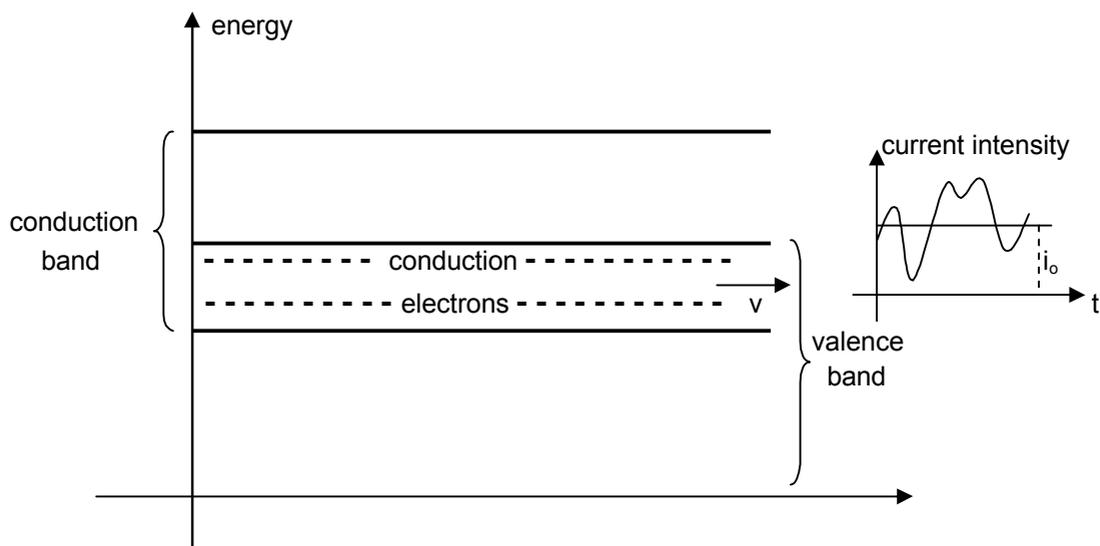


Figure 1. A constant voltage provides electrons with velocity v and generates a constant current i_0 . Modulation of current intensity of conduction electrons by a voltage signal allows the generation of an electromagnetic wave.

The variable current in the metal generates an electromagnetic field in dielectric space that allows the propagation of electromagnetic waves with the speed of light. The electromagnetic field is described by Maxwell's equations: in the paragraph 6 we will bring a formal change in these equations.

If the electromagnetic wave is monochromatic it is characterized by a wavelength λ_r tied to the frequency f_r by the relationship $\lambda_r f_r = c$ and is represented by a time and space function $f(x,t)$ (radiation intensity) for which considering a precise time, for instance $t=0$, the radiation has for example the space trend as in fig.2.

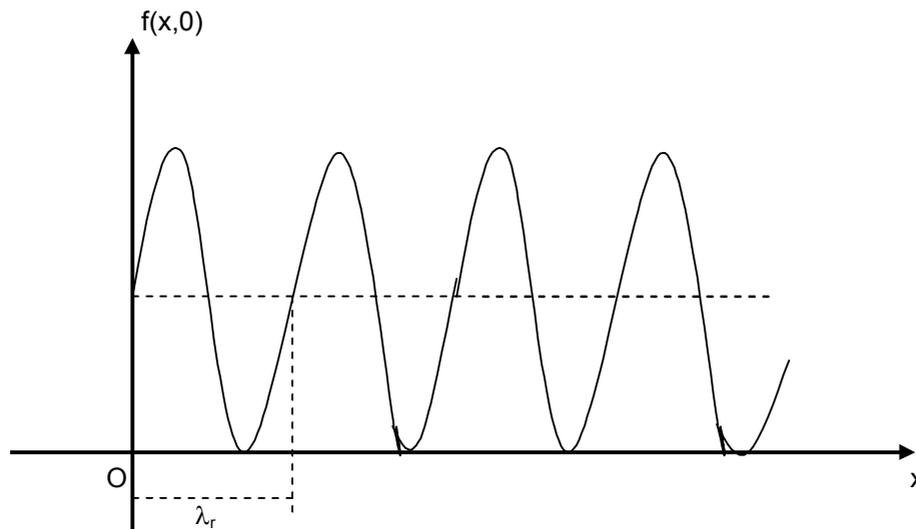


Figure 2. The diagram represents the space trend of a monochromatic electromagnetic wave at time $t=0$.

It is manifest the electromagnetic field has a wave nature but this property doesn't involve the necessity of a transmissive medium because waves are generated by oscillations of the electromagnetic field. Increasing the frequency, the wavelength decreases and this process has a threshold. This threshold is represented by the maximum frequency that can be obtained with respect to the variation of current intensity that is limited by velocity of electrons in metals. The threshold is localizable at the 300GHz frequency where the infrared radiation begins. This threshold represents in our theory the transition frequency from the energy wave to the energy corpuscle, from the continuous structure to the discontinuous structure of radiant energy.

3. On the physical nature of light

Light is a photon beam and therefore it has corpuscular nature. Photons are energy quanta and are generated by quantum jumps of electrons between two energy levels of atom or between two energy bands of molecule (fig.3).

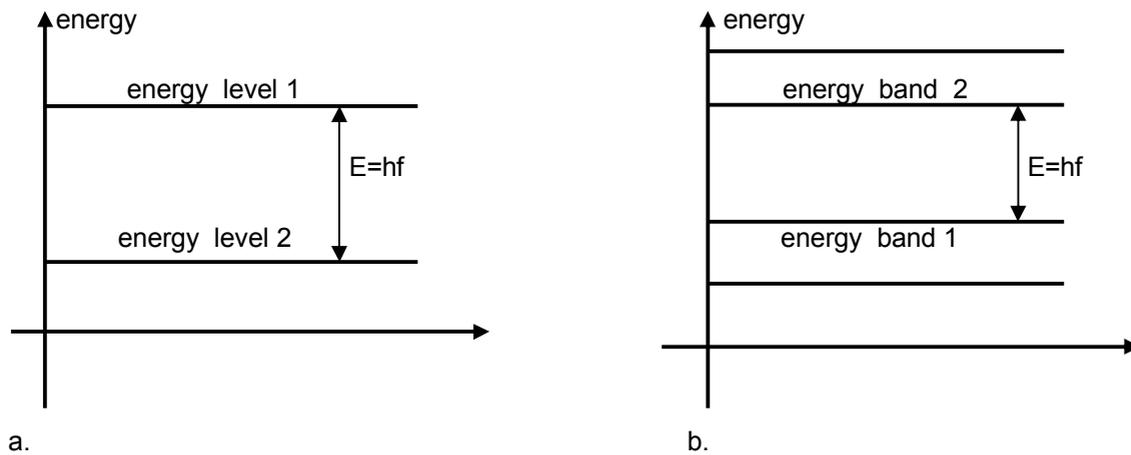


Figure 3. Generation of photons
 a. Atomic photons
 b. Molecular photons

All photons are characterized by a frequency f and by a wavelength λ with $f\lambda = c$ where c is the speed of photons and light. Really photons cover a very wide frequency spectrum from 300GHz to 3×10^{10} GHz that comprises the infrared radiation (300GHz - 4×10^5 GHz), the visible radiation (4×10^5 GHz - 8.5×10^5 GHz), the ultraviolet radiation (8.5×10^5 GHz - 3×10^7 GHz) and X-rays (3×10^7 GHz - 3×10^{10} GHz). Intensity of photon beam can be constant or variable like in fig.4.

We can define a function $N(x,y,z,t)$, called "photonic energy potential", that specifies the number of photons present at time t in the space point with coordinates x,y,z . According to figure 4 let's suppose that propagation happens along the axis x , for which y and z coordinates aren't revealing. At time $t=0$ $N(x,0)$ represents for every x the number of photons present at abscissa x with $N \geq 0$. If $E_f = hf_f$ is the energy quantum associated with the single photon, that we suppose all equal, then

$$E = N(x,0) E_f \quad (1)$$

is the total energy associated with the photon beam at time $t=0$ in the point with abscissa x . If photon beam is monochromatic (fig.4.b) it propagates in the space with wave motion and therefore the photonic energy potential N must respect d'Alembert's wave equation

$$\Delta N = \frac{1}{c^2} \frac{\delta^2 N}{\delta t^2} \quad (2)$$

in which c is the speed of radiation and Δ is the Laplace operator.

The equation (2) represents the digitization of luminous energy and explains very well that in order to propagate light has no need of any medium. If the photonic energy potential is constant (fig.4.a) the d'Alembert equation loses meaning.

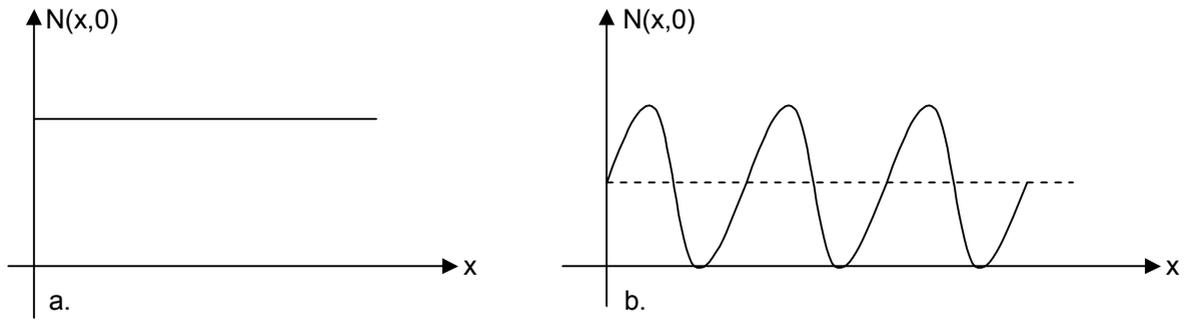


figure 4. Photon beams
 a. Photon beam with constant intensity
 b. Photon beam with monochromatic variable intensity

4. Diffraction and Fourier integration

We obtain diffraction of radiant energy when in its path it meets a slot or an obstacle. If radiation of energy is monochromatic with wavelength λ_0 (fig.5.a) [in the event of light $N(x,t_0)$ and in the event of electromagnetic wave $f(x,t_0)$ are represented for example by a cosine curve in every space point at time $t=t_0$] we know the passage of radiant energy through the slot with length $X_0 \approx \lambda_0$ produces diffraction like in fig.5.b.

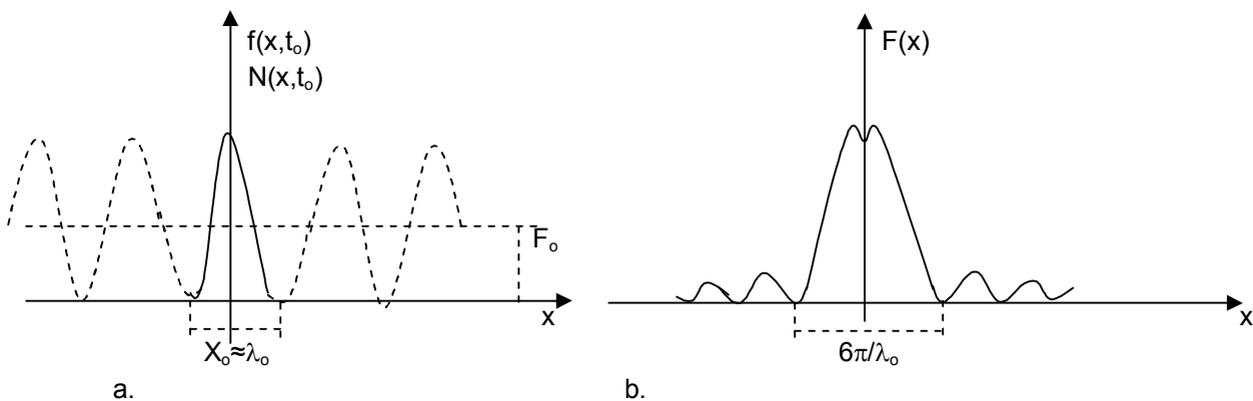


Figure 5. A monochromatic radiation of energy with wavelength λ_0 meets a slot with length $X_0 \approx \lambda_0$.
 a. Radiation is monochromatic before the slot and it is cut and bounded by the slot.
 b. Diagram gives the trend of radiant energy on the screen with the alternation of patches of light (maximum points) and patches of shade (minimum points).

If now we calculate the Fourier integral of the following function representing the radiation of energy after the slot

$$N(x,t_0) = f(x,t_0) = \begin{cases} F_0 + F_0 \cos 2\pi x / \lambda_0 & \text{for } -\lambda_0/2 \leq x \leq +\lambda_0/2 \\ 0 & \text{for } -\lambda_0/2 > x > +\lambda_0/2 \end{cases} \quad (3)$$

we have

$$F(k) = C_0 \frac{\text{sen}2\pi k\lambda_0/2}{2\pi k\lambda_0/2} + \frac{C_0}{2} \frac{\text{sen}2\pi(k-k_0)\lambda_0/2}{2\pi(k-k_0)\lambda_0/2} + \frac{C_0}{2} \frac{\text{sen}2\pi(k+k_0)\lambda_0/2}{2\pi(k+k_0)\lambda_0/2} \quad (4)$$

where $k=1/\lambda=1/X$ and $C_0=F_0\lambda_0/\sqrt{2\pi}$.

In surprising way the relation (4) is in good concordance with the diagram 5.b and we have many reasons to think this concordance has rather a causal than casual meaning.

If radiation of energy is constant (this situation can occur only in the event of light and the photonic energy potential N is in that case constant in every space point at every time t_0) (fig.6.a) the passage of radiant energy through the slot with length X_0 produces diffraction like in fig.6.b.

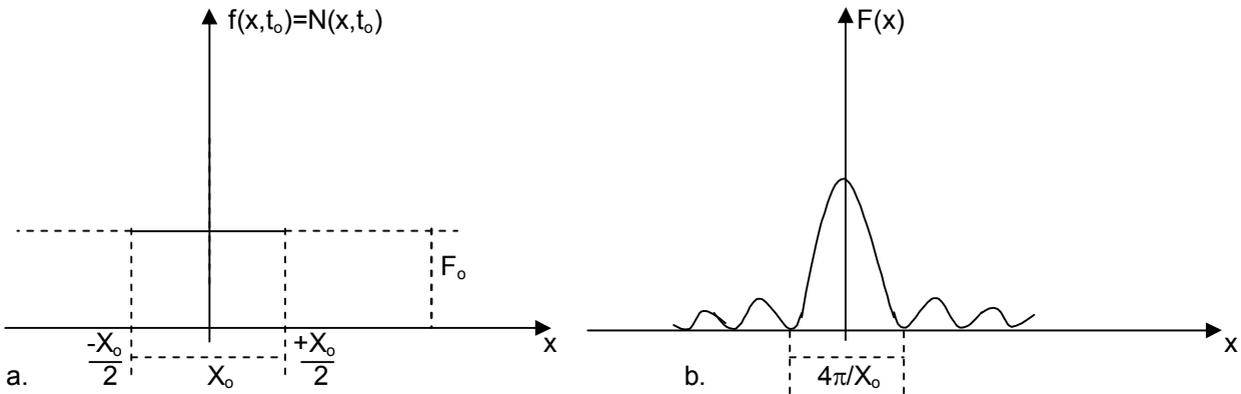


Figure 6. A constant radiation of light meets a slot with length X_0 .
 a. Radiation is constant before the slot and it is cut and bounded by the slot.
 b. Diagram gives the trend of light on the screen with the alternation of patches of light (maximum points) and patches of shade (minimum points).

The function representing the radiation after the slot in fig.6.a is

$$f(x, t_0) = \begin{cases} F_0 & \text{for } -X_0/2 \leq x \leq +X_0/2 \\ 0 & \text{for } -X_0/2 > x > +X_0/2 \end{cases} \quad (5)$$

for which we have the following Fourier integral represented in fig.6.b

$$F(k) = C_1 \frac{\text{sen}2\pi kX_0/2}{2\pi kX_0/2} \quad (6)$$

where $k=1/X$ and $C_1=F_0X_0/\sqrt{2\pi}$.

5. Behaviour of radiant energy in regard to diffraction

In our representation radiant energy is basically an electromagnetic wave for frequencies smaller than the threshold frequency and a flux of photons for greater frequencies where the flux of photons can be constant or variable. If photons in a point of space are N and everyone is equal to $E_f = hf_f$ the intensity of radiant energy in that point is given by the total energy $E = NE_f = Nhf_f$ ($N \geq 0$).

Let us consider now an energy monochromatic radiation (electromagnetic wave or light), emitted by the source S , and let's suppose still that the radiation meets along its path a screen S_i that has a slot with length X_o (fig.7) : the considered physical situation generates diffraction.

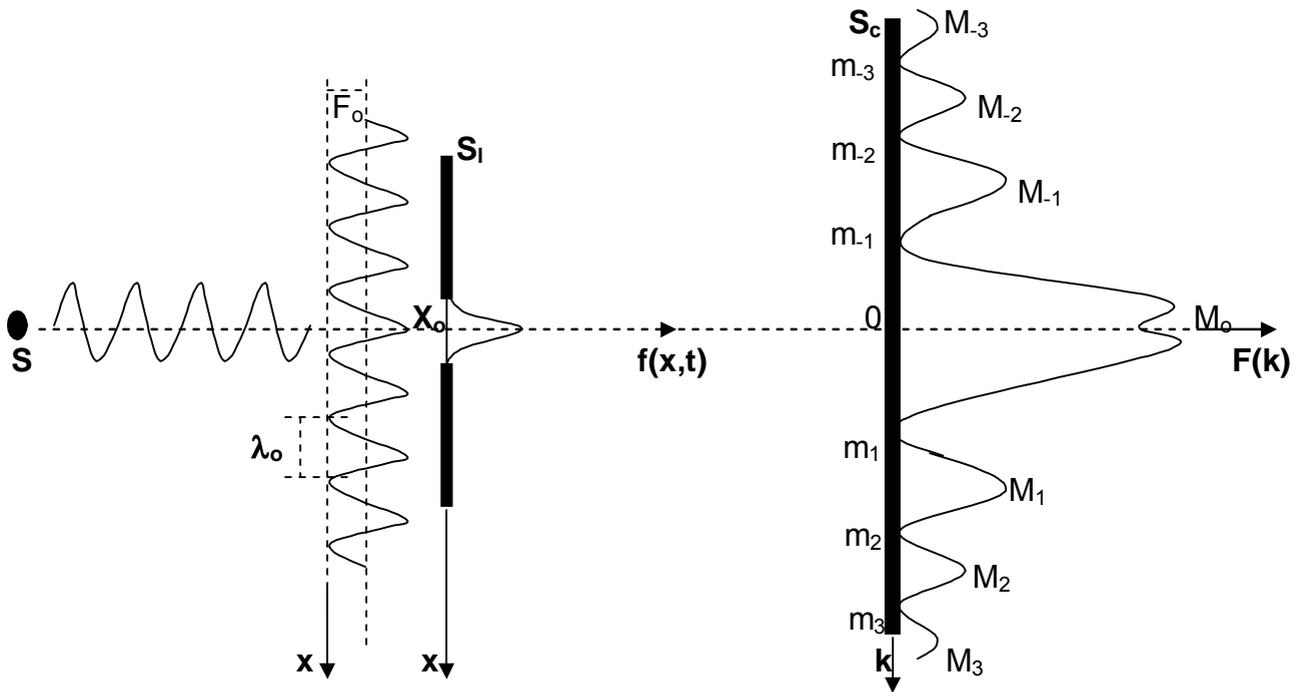


Figure 7. The energy radiation emitted by the source S is monochromatic and propagates along the horizontal axis, it is plane on the screen S_i with slot. In figure we suppose that the length X_o of the slot is equal to wavelength λ_o of the radiation. On the screen S_c the received energy is represented on the axis $k=1/\lambda=1/X$ and presents decreasing maxima M of light and minima m in which there are patches of shade.

Before the slot the radiation is monochromatic along the horizontal axis and plane along the axis x , the space mathematical representation of radiation at time t_o is

$$f(x,t_o) = F_o + F_o \cos \frac{2\pi x}{\lambda_o} \quad \text{for} \quad -\infty < x < \infty \quad (7)$$

The screen with slot cuts and bounds the radiation and supposing that $X_o \approx \lambda_o$ on the slot there is only one wave cycle. The space mathematical representation of radiation on the slot is at time $t_1 > t_o$

$$\begin{cases} f(x,t_1) = F_0 + F_0 \cos \frac{2\pi x}{\lambda_0} & \text{for } -\frac{\lambda_0}{2} \leq x \leq \frac{\lambda_0}{2} \\ f(x,t_1) = 0 & \text{for } x < -\frac{\lambda_0}{2} \text{ and } x > \frac{\lambda_0}{2} \end{cases} \quad (8)$$

The mathematical representation of radiation on the screen S_c is given with good approximation by the Fourier integral (the function $f(x,t_1)$ is even)

$$F(k) = C_0 \frac{\sin 2\pi k \lambda_0 / 2}{2\pi k \lambda_0 / 2} + \frac{C_0}{2} \frac{\sin 2\pi(k-k_0)\lambda_0 / 2}{2\pi(k-k_0)\lambda_0 / 2} + \frac{C_0}{2} \frac{\sin 2\pi(k+k_0)\lambda_0 / 2}{2\pi(k+k_0)\lambda_0 / 2} \quad (9)$$

The function $F(k)$ represents the intensity of radiation on the screen in regard to the wave number $k=1/\lambda$. Like this we have explained completely and correctly the physical event of diffraction whether in the wave theory of electromagnetic field or in the corpuscular theory of light.

If light emitted by source has constant intensity instead of a monochromatic trend (fig.8), applying the Fourier integral we obtain the equation (6).

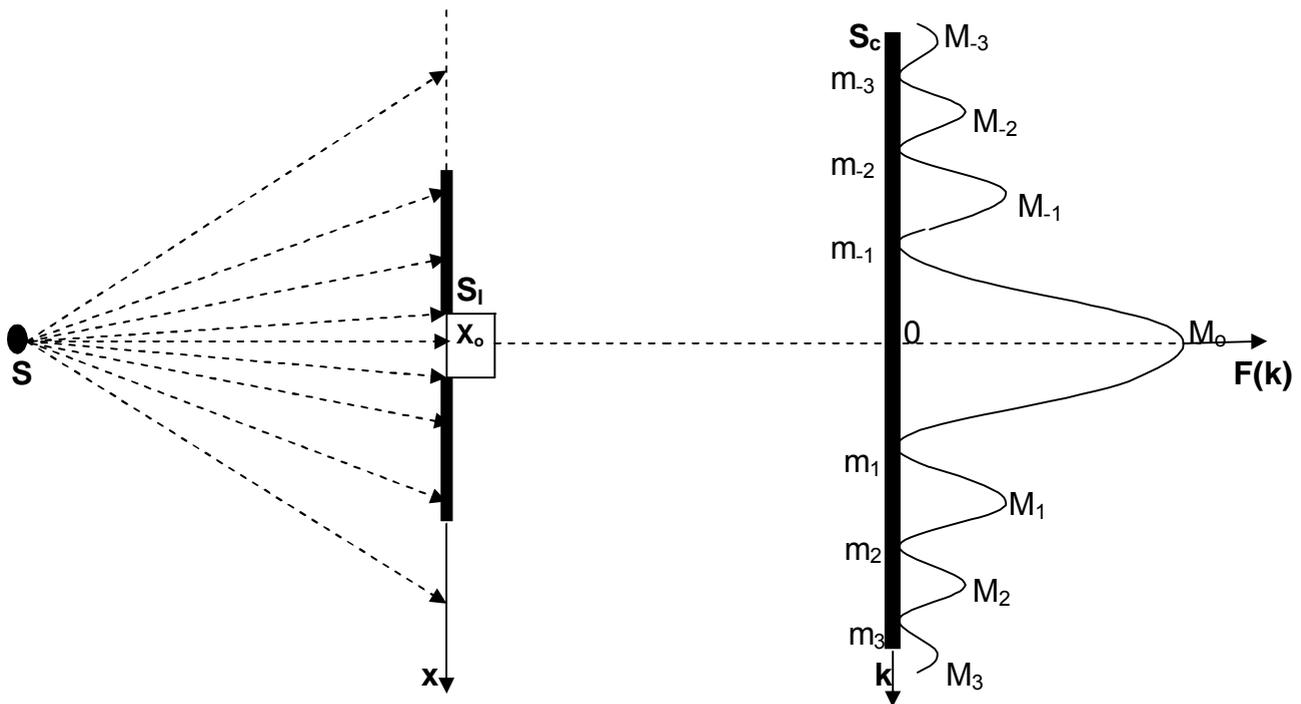


Figure 8. The radiation of energy emitted by the source S is a constant flux of photons and propagates along the horizontal axis. In figure we suppose that the slot has length X_0 . On the screen S_c the received light is represented on the axis $k=1/X$ and presents decreasing maxima M of light intensity and minima m in which there are patches of shade.

We are therefore able to claim that the slot for the radiation represents a Fourier integrator.

If we consider two slots placed at small mutual distance we are able to study also the physical event of interference in which similarly alternation of patches of light and patches of shade is observed. If radiation of energy meets an obstacle this physical situation is equivalent to interference with two slots.

6. The new group of Maxwell's equations

In order to describe a physical event a group of equations must have three essential requirements:

- All equations must be independent of each other like no equation can be derived from another or from the combination of more equations of the group.
- There is no need to make use of other independent equations outside the group for the complete description of the physical event.
- No equation of the group must be a mathematical identity.

We know an electromagnetic event is described by the following four equations^[1] (Maxwell's equations) with respect to the reference frame, supposed at rest, where the event happens

$$\operatorname{div} \mathbf{E} = \frac{\rho}{\varepsilon_0} \quad (10) \qquad \operatorname{div} \mathbf{B} = 0 \quad (11)$$

$$\operatorname{rot} \mathbf{E} = - \frac{\delta \mathbf{B}}{\delta t} \quad (12) \qquad \operatorname{rot} \mathbf{B} = \mu_0 \mathbf{J} + \frac{1}{c^2} \frac{\delta \mathbf{E}}{\delta t} \quad (13)$$

The four equations are written into the differential and vectorial format and each of them has a specific physical meaning. In the equation (10) the electric field is static and ρ is the electric charge density. In the (13) c is the speed of light and like this Maxwell demonstrated electromagnetic waves have the same speed of light. Moreover the speed of both, light and electromagnetic waves, depends on medium where propagation happens only through the refractive index, that is the ratio between the speed of light in a vacuum and the speed of light in the considered medium.

We know nevertheless the four equations aren't sufficient to describe the entire electromagnetism because the following equation of continuity of electric charge must be added to them

$$\operatorname{div} \mathbf{J} = - \frac{\delta \rho}{\delta t} \quad (14)$$

This equation, itself also written into differential format, expresses the principle of

conservation of electric charge in variable regime. Moreover also the Lorentz force $\mathbf{F} = q\mathbf{u} \wedge \mathbf{B}$ acting on an electric charge q moving with speed \mathbf{u} in a magnetic field \mathbf{B} is important to describe electromagnetic phenomena in physical situations where electric charges move. Therefore let us construct now a single group of four equations in order to describe completely electromagnetic phenomena with respect to reference frames at rest without making use of further equations.

We can observe to that end the equation (11) gives always the same information, i.e. the magnetic field doesn't have single magnetic sources and therefore there aren't magnetic monopoles. For this reason the equation (11) is a mathematical identity and is not necessary for the group of equations. It can be usefully replaced by Lorentz's force that instead is always necessary to describe electromagnetic phenomena with moving electric charges.

We observe still the equation (10) can be derived by adequate calculations from the equations (13) and (14). In fact as per a renowned property of the rotation operator (rot) we know that for each vector \mathbf{A} we have always $\text{div rot } \mathbf{A} = 0$ and therefore from the eq. (13) we deduce

$$\text{div rot } \mathbf{B} = \text{div} \left(\mu_0 \mathbf{J} + \frac{1}{c^2} \frac{\delta \mathbf{E}}{\delta t} \right) = 0 \quad (15)$$

$$\mu_0 \text{div} \mathbf{J} + \frac{1}{c^2} \text{div} \frac{\delta \mathbf{E}}{\delta t} = 0 \quad (16)$$

Exchanging place of the divergence operator with the operator "time derivative", as per the eq. (14) we can write

$$\frac{1}{c^2} \frac{\delta}{\delta t} \text{div } \mathbf{E} - \mu_0 \frac{\delta \rho}{\delta t} = 0 \quad (17)$$

from which

$$\frac{\delta}{\delta t} \left(\text{div } \mathbf{E} - \frac{\rho}{\epsilon_0} \right) = 0 \quad (18)$$

$$\text{div } \mathbf{E} - \frac{\rho}{\epsilon_0} = K \quad (K \text{ is constant in time}) \quad (19)$$

For stationary fields (electric charges are still or move with constant speed) the electric field is given by^[1]

$$\mathbf{E} = \mathbf{E}_{\text{static}} + \rho_t \mathbf{J} \quad (20)$$

and therefore from (19) and (10)

$$\rho_t \operatorname{div} \mathbf{J} = K \quad (21)$$

where ρ_t is the resistivity of medium in which direct current flows.

For static fields (electric charges are still) $\mathbf{J} = 0$ and therefore $K=0$, from the (19) finally we have the (10)

$$\operatorname{div} \mathbf{E} = \frac{\rho}{\varepsilon_0} \quad (22)$$

where ρ is the electric charge density.

Like this we have proved that the following group of equations (“Maxwell’s rationalized equations”) is able to describe completely all electromagnetic phenomena without using other equations

$$\operatorname{div} \mathbf{J} = - \frac{\delta \rho}{\delta t} \quad (23) \qquad \mathbf{F} = q\mathbf{u} \wedge \mathbf{B} \quad (24)$$

$$\operatorname{rot} \mathbf{E} = - \frac{\delta \mathbf{B}}{\delta t} \quad (25) \qquad \operatorname{rot} \mathbf{B} = \mu_0 \mathbf{J} + \frac{1}{c^2} \frac{\delta \mathbf{E}}{\delta t} \quad (26)$$

7. Propagation of photon

In all our considerations on the propagation of radiant energy the concept of ether, like transmissive medium, never appears because whether in the wave theory of electromagnetic field or in the corpuscular theory of light the ether isn’t necessary to explain phenomena of propagation and diffraction likewise it isn’t necessary to explain the issue of relativity^[2].

All the attempts made by several scientists in order to save the ether and surpass the paradoxes of the Theory of Special Relativity don’t have achieved the objective: here we remind for instance “the dispersion in a discretely structured vacuum” by S. Jovicevic^[3], “the concept of the Lorentz contraction as real contraction of objects” by R.T. Cahill^[4] and “the simultaneous dilation-contraction of a rigid rod” by G. Zanella^[5]. The answer to contradictions of Special Relativity is the Theory of Reference Frames^[6] in which a preferred reference frame and a preferred observer are considered but they are quite another matter with respect to the absolute reference frame and to the ether.

Radiant energy, whether in the shape of electromagnetic waves or light, propagates in the space with velocity $c \approx 300000\text{km/s}$. This velocity is deduced from Maxwell’s equations and is confirmed by experimental result. In order to complete the theory of radiant energy here displayed we must explain now the nature of photon.

Photon is a quantum of radiant energy that is produced by a quantum jump of

electron between two energy levels of atom and propagates in the space with velocity c . Electron jumping between two different levels of energy and velocity is a moving electric charge equivalent to a variable nanocurrent that generates in the immediately surrounding space an electromagnetic nanofield. In this viewpoint the photon is an electromagnetic nanowave that travels at the velocity of light. Equations of electromagnetic nanofield connected with photon are derivable from Maxwell's equations. Electron generating a photon moves in the electric field with central symmetry ($E=Ze/r^2$) of atom nucleus with velocity $v=\delta r/\delta t$. We can write therefore, being $J=0$, Maxwell's (26) equation like this

$$\text{rot } \mathbf{B} = \frac{v}{c} \frac{\delta \mathbf{E}}{\delta r} \quad (27)$$

Finally we are able to claim therefore the following equations describe the beginning (eq. 28) and the propagation (eq. 29 and 30) of the electromagnetic nanofield connected with photon

$$\left\{ \begin{array}{l} \text{rot } \mathbf{B} = \frac{v}{c} \frac{\delta \mathbf{E}}{\delta r} \quad (28) \\ \text{rot } \mathbf{E} = - \frac{\delta \mathbf{B}}{\delta t} \quad (29) \\ \text{rot } \mathbf{B} = \frac{1}{c} \frac{\delta \mathbf{E}}{\delta t} \quad (30) \end{array} \right.$$

References

- [1] G. Cortini, Lessons of Physics (Electromagnetism), edited by Liguori Editor (Naples), 1969, p. 385
- [2] D. Sasso, Is the speed of light invariant or covariant ?, arXiv.org, id: 1003.2273, 2010
- [3] S. Jovicevic, Wave Propagation and Particle Motion through a Discretely Structured Vacuum, Physics Essays, Volume 20 (2007), No. 2
- [4] R. T. Cahill, Lunar Laser-Ranging Detection of Light-Speed Anisotropy and Gravitational Waves, arXiv.org, id: 1001.2358, 2010
- [5] G. Zanella, Lorentz Contraction According to the Wave Nature of the Light, arXiv.org, id: 1003.4833, 2010
- [6] D. Sasso, Relativistic Effects of the Theory of Reference Frames, Physics Essays, Volume 20 (2007), No.1